

EFACA Aircraft Noise in Flight and Ground Operations on a Roadmap to ACARE Noise Goals [†]

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Abstract

This paper presents an integrated assessment of aircraft noise in flight and ground operations within the EFACA project, supporting the roadmap toward ACARE Flightpath-2050 noise goals. It summarizes required reductions, evaluates current technology readiness, and analyzes contributions from advanced propulsion concepts, propeller-noise modeling, and operational procedures. New seven-bladed propeller designs, validated through semi-empirical, analytical, and CAA methods, demonstrate substantial tonal-noise improvements, influencing the aircraft noise reductions by 2–4 dB depending on the flight stage, and during the ground operation by up to 5 dB.

Keywords: aircraft noise; propeller aeroacoustics; noise reduction technologies; ground operations noise; sound exposure level; ACARE Flightpath 2050

1. Introduction

Noise goals of Advisory Council for Aviation Research and Innovation in Europe (ACARE) drive a comprehensive mix of technology, operation, and land-use actions covering both in-flight and ground activity. This paper summarizes the goals and reports on progress, and proposes a practical, operationally oriented roadmap of measures, with quantifiable metrics that are designed to achieve the ACARE/Fly the Green Deal (2022) noise targets. While the ACARE Fly the Green Deal goals are structured around the same four pillars as the ICAO Balanced Approach (BA)—Technology, Operations, Land-Use Planning, and Restrictions—the difference lies in the magnitude, integration, and necessity of disruptive innovation required to achieve the targets.

ACARE's goals represent a revolutionary leap, rather than the constant, incremental improvement that is traditionally associated with ICAO BA, and primarily in aircraft design, including quieter and cleaner powerplants and airframes.

2. Summary of ACARE/Fly the Green Deal Noise Targets

The core long-term goal defined by ACARE is a ~65% reduction in the perceived noise energy of a typical aircraft operation by 2050, relative to a 2000 baseline, which is equivalent to a 15 EPNdB reduction at ICAO certification per single aircraft operation. Complementary



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targets focus on population exposure around airports, specifically preventing the growth of populations living within the $L_{den} = 55$ dB noise contour in 2030, relative to a 2019 baseline, which is equivalent to a 3 EPNdB reduction per single aircraft operation, due to current forecasts for air traffic growth until 2030–35. These assessments show measurable progress but confirm that additional technical and operational measures are required to achieve the ambitious 2050 goal.

3. Sources of Required Noise Reduction

Noise reductions must be achieved through concurrent efforts across four domains:

- **Airframe and engine design:** Quieter engine nacelles equipped with acoustic liners and chevrons, advanced low-noise high-bypass engine designs, airframe shielding, and optimization of noise generated by the landing gear and high-lift devices (flaps).
- **Operational procedures/air traffic management:** Implementation of continuous descent and climbing operations and reduction in level-flight/level segments in terminal airspace near airports.
- **Ground operations and airport measures:** Implementation of electric taxiing, replacement of auxiliary power units (APU) with ground power or electric APUs, electrification of ground service equipment, and optimized aircraft taxi routing.
- **Land-use and policy:** Effective land-use planning (to prevent population growth within the noise zoning contours) and regulatory instruments such as noise action plans or local operating restrictions in airports.

Figure 1 shows noise reduction technologies (NRT) that have a direct and indirect influence on noise produced by airplane propulsion and airframe acoustic sources.

Noise						Metric
Propulsion				Airframe		Domain
Propeller	Jet	Engine	Novel configurations	Wing	Landing Gear	
Variable pitch	Ultra high bypass ratio engines	Porous materials on OGV	Blended-wing body		Fairings	HLD edges made of porous materials
Optimal number, shape, distribution of the blades	Micro jet devices	3D-optimized blade design	Full-electric propulsion	Vortex generators	Rims on wheels	
	Chevrons	Refining the shape, spacing, and number of blades	Distributed electric propulsion	Engine shielding	Caps on cavities	Slat gap optimization or suppression
	Fan flow deflector	Active stators			Brush at the trailing edge	Droop nose at the leading edge
Lobed mixers	OGV-integrated actuators	Fractal spoilers				
Bio-mimetic propeller design	Translating plug	3D printing of gas-turbines	Continuous Mold-Line Link flap			
Leading and trailing edge serrations	Zigzag vortex generator nozzle	Reduction in fan pressure ratio				
	Wavy inner wall treatment	Reduction in fan tip speed				
		Increase in size of fan				
Pylon blowing		Water-enhanced turbofan				
		Liners				

Technologies

*Sampling -not inclusive list

Figure 1. Variety of NRT in aircraft propulsion and airframe designs.

Generally, all noise reduction technologies rely one of four principles:

1. Reduce gas flow speed (engine or airframe) and make flow speed distribution uniform;
2. Absorb sound waves using acoustic treatments on engine or airframe surfaces;

3. Shield acoustic waves by airframe along the propagation path to the listener;
4. Generate smaller vortices instead of large ones to redistribute noise to higher frequencies, which decrease more intensively with distance in the atmosphere.

Both EFACA aircraft concepts—hybrid-electric propulsion (HEP) and liquid hydrogen propulsion (LH2) are important for AN modeling assessment. For an LH2 aircraft, the engine is suggested as an ultrahigh bypass design with available NRT. Most important is the designing of the new propeller for the HEP aircraft to provide the best acoustic performances of the propeller itself and the reduced overall aircraft noise up to the ICAO limits in general. In Figure 2, the current CAD version of the EFACA propeller geometry is shown. Its main parameters, and especially the form of the blade, is confirmed by computational aerodynamic code [1], from which the results are used for the following acoustic calculation analysis, in accordance with the main flight profile data for the HEP aircraft (Table 1).

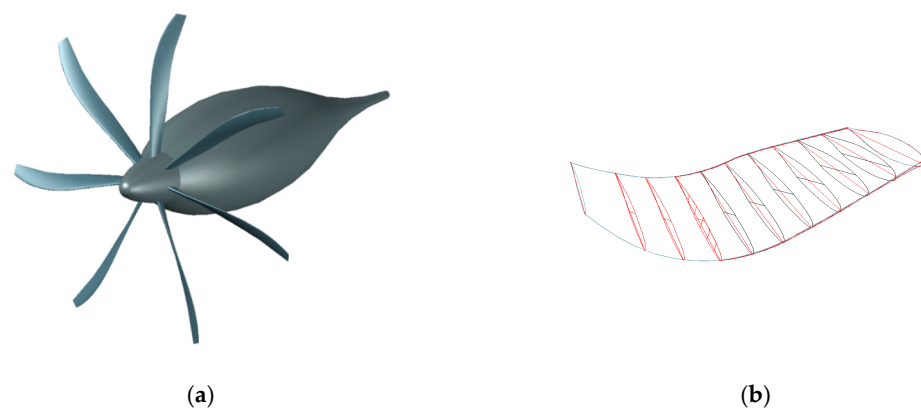


Figure 2. Seven-bladed propeller for the EFACA HEP aircraft (a) and its blade geometry (b) optimized to aircraft flight profile.

Table 1. Airplane flight profile points for the propeller performance assessment [1].

Flight Phase	HEP Rating	Altitude, m	Mach Number	Velocity, M/C
Take off	Normal TO	0	0.1714	58.32
		400	0.1722	58.33
Climb to cruise altitude	Max Climb Max Cruise	400	0.36	121.94
		6100	0.36	113.76
Cruise	Max Cruise	6100	0.45	142.20
Descent	Flight Idle	6100	0.32	101.12
		400	0.32	108.39
Descent and landing	Flight Idle	400	0.1722	58.33
		0	0.1714	58.32

The contribution of the propeller noise for both flight modes—arrival and departure—to the overall spectrum is dominant; thus, the NRT should be provided to reduce the propeller noise in the source, with the main goal being overall aircraft noise reduction. Typical propeller noise mitigation strategies concentrate on shape optimization, including global parameters such as the propeller radius and the number of blades, and local parameters, such as the chord, twist, and sweep distributions along the radius. All these conventional methods are still a subject of ongoing research via CFD modeling, together with several unconventional methods [2]. In our case, such an NRT is obtained by designing

a new propeller with seven blades (six blades are in the Hamilton HS 568F propeller for the PW-127 of the reference aircraft ATR72-600) with very specific blade geometry (Figure 2) optimized by CFD modeling. The preliminary results for the new EFACA propeller noise assessment by the NoiTra model is shown in Figure 3 and Table 2. Three types of the calculation models are used: the semi-empirical PROPELLER module of the NoiTra calculation tool achieving the standard [3] recommended for propeller noise assessment (L_{prop_old} in Figure 3a) by ICAO Manual [4]; an analytical model modified from the Gutin model [5]; and the direct computational aeroacoustics (CAA) method [2]. Noise measurement results (SPL_{prop_AT76} in Figure 3a) in Katowice airport were used for the clarification of calculated results by the NoiTra model, including the consideration of dominant acoustic sources and sound propagation effects [6].

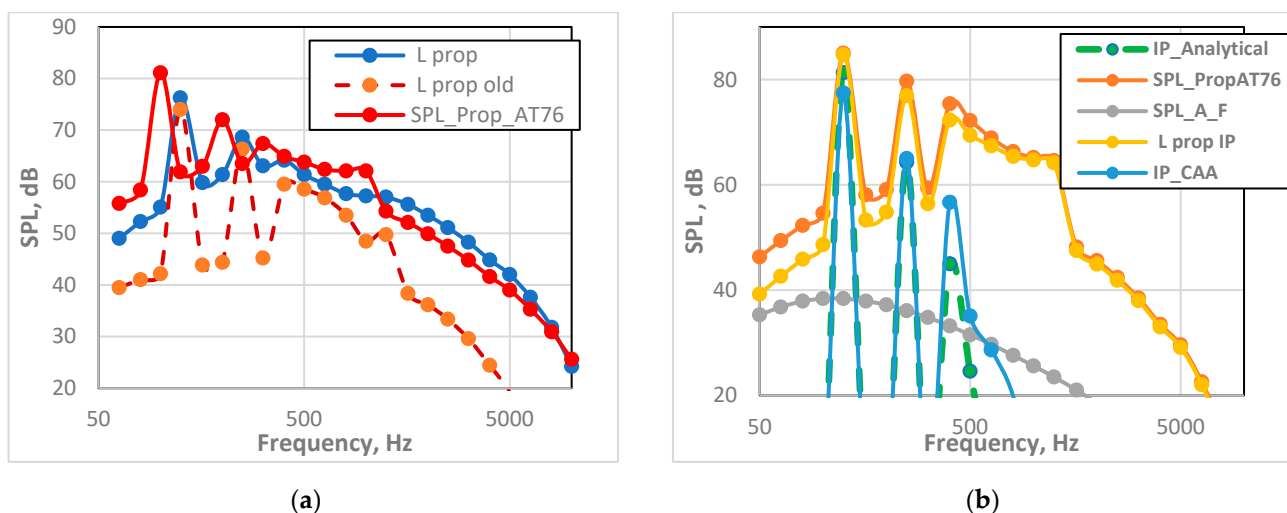


Figure 3. Calculated EFACA propeller noise (blue line); the dashed line is for the calculated spectrum by the previous NoiTra model: (a) comparison with measured ATR72-600 (red line) and (b) comparison with analytical and CAA calculation results.

Table 2. Comparison of the tonal components of the propeller noise by analytical, CAA and semi-empirical models.

Method		Harmonic Frequency f_{tonal} , Hz					
		128.3	256.7	385.0	513.3	641.7	770.0
Empirical	L_{tonal} , dB	84.15	74.9	70.6	68.6	66.5	65.4
Analytical	L_{tonal} , dB	81.3	65.1	45	24.6	3.4	−18.3
CAA	L_{tonal} , dB	77.5	65	56.7	35.1	28.7	19.8
Diff	ΔL_{tonal} , dB	3.0–7.0	10	>20	>30		

The NoiTra calculation results fit well with the measurements in real operation (Figure 3) and further spectral and temporal analysis allows for a much better understanding of noise generation and their propagation effects at points of interest and reduction HEP aircraft noise in flight. The EFACA propeller tonal noise is assessed by analytical and CAA models—the first two harmonics are compared well between themselves, showing a 3 and 10 dB difference with a semi-empirical model (Table 2), which are considered to be noise reduction achieved by optimized CFD modeling of the blade geometry (Figure 2). The overall 3 dB reduction in EFACA propeller noise compared to the Hamilton propeller reference noise level appears to be sufficient to meet the short-term ACARE noise target.

EU INVENTOR project (<https://w3.onera.fr/inventor/en> accessed on 16 April 2026) investigated the NRT for the airframe acoustic sources. Its primary goal was to better understand the physics of noise generated by landing gears and wing high-lift devices, due to the intensive use of advanced CAA methods through the development of NRT for landing gears and high-lift devices' acoustic components. Mounting support, fairing frame and porous fairings installed over the landing gear strut provide noise reduction of 5–10 dB. The effect of the correct slat-gap filler installation in wing high-lift devices may reach ~10 dB of noise reduction. Despite significant noise reductions observed at component levels, the combination of several NRTs can produce 2 EPNdB reduction at approach and ~4EPNdB at departure, comparing HEP baseline with ATR72-600 reference levels.

4. Noise in Aircraft Flight Operations

The baseline air traffic scenario (ATR72-600 or HEP aircraft contribution assessment) was analyzed further for the EFACApport layout [7], including appropriate fleet and traffic structure in the EU regional airport. In Figure 4, the EFACA HEP concept continues to demonstrate the moderate reductions in the contour area compared to the reference aircraft ATR72-600. The virtual EFACApport traffic scenario confirms the possibility of increasing to 20% of air traffic in 2035 without an increase in the existing noise zones in regional airports if the aircraft fleet includes the EFACA HEP aircraft instead of ATR72-600.

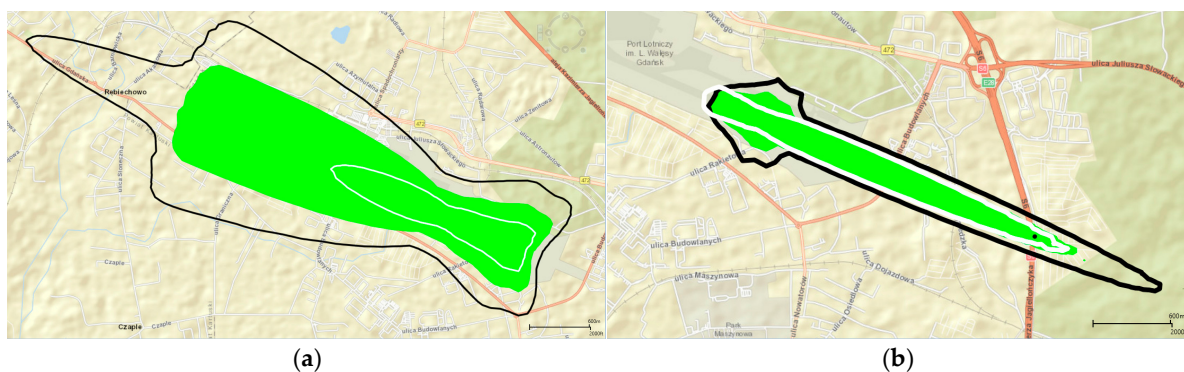


Figure 4. Noise footprints 90 EPNdB for the departure (a) and approach (b) of the ATR-72-200 (black line), ATR-72-600 (green area), and EFACA HEP (white line within the green area): ICAO certification points are shown in comparison to footprint boundaries.

The EFACApport noise modeling results for L_{den} and L_{night} (Figure 5) highlight the higher noise levels associated with older aircraft NRT. Across all scenarios, the LH₂/HEP configurations have the greatest relative impact on departure-driven exposure, particularly where early-climb LH₂ aircraft engine thrust is a dominant contributor to community noise.

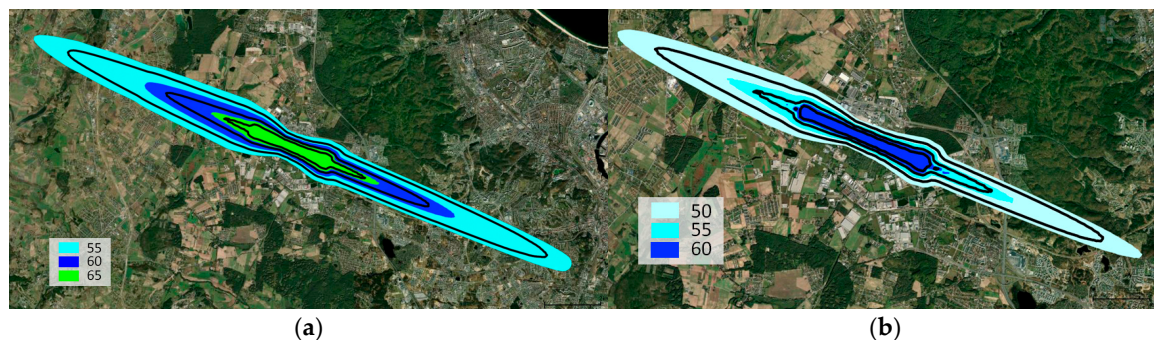


Figure 5. EFACApport noise scenario L_{DEN} (a) and L_{night} (b) analysis for 2019 (colored footprints) and 2035 (isolines): transition from CEO/ATR-72-200 to LH₂/HEP aircraft fleet [6].

In a longer perspective—the ACARE 2050 noise goal of 65% perceived noise reduction compared with the 2000-year aircraft technology design—further improvements in the propulsion and airframe of NRT are still necessary for both EFACA designs, as for conventional turboprops and turbofans.

5. Noise in Ground Operations

The propeller noise was investigated as the dominant noise source during aircraft taxiing. As a reference case, the taxiing of the ATR-72-600 in Gdansk airport was considered based on Flightradar24 data. The procedure of the estimation of velocity and acceleration dependence on distance from the Flightradar24 data was described in [7].

To compute the sound pressure level (SPL) in a local coordinate system of an airport, 0xyz, the coordinates of the separate acoustic sources—the propeller of the first engine (x_{1e}, y_{1e}) and the propeller of the second engine (x_{2e}, y_{2e})—are described by the following formulas:

$$x_{1e} = x_{CG} + (o\Delta y_s + d\Delta x_s)\zeta; \quad (1)$$

$$y_{1e} = y_{CG} + (-o\Delta x_s + d\Delta y_s)\zeta; \quad (2)$$

$$x_{2e} = x_{CG} + (-o\Delta y_s + d\Delta x_s)\zeta; \quad (3)$$

$$y_{2e} = y_{CG} + (o\Delta x_s + d\Delta y_s)\zeta, \quad (4)$$

where $o = \frac{R_{eng}}{2}$, R_{eng} is the distance between engine axes (for ATR-72-600 $R_{eng} = 8.1$ m), d is the distance to the propeller from the center of gravity along the fuselage axis ($d = 2.75$ m); $\zeta = \frac{1}{\sqrt{\Delta x_s^2 + \Delta y_s^2}}$; and x_{CG} and y_{CG} are the coordinates of the aircraft center of gravity during motion along the trajectory. The aircraft coordinates are calculated based on the arc length l . For this, the coordinates of the points on the curve from Flightradar24 are interpolated using the arc length l : for example, with the “interparc” function [8]. To compute Δx_s and Δy_s additional interpolation is done with a very small increment to the arc length l , resulting in coordinates x_{CGi} and y_{CGi} . $\Delta x_s = x_{CGi} - x_{CG}$. $\Delta y_s = y_{CGi} - y_{CG}$. This allows us to consider the direction of the aircraft motion.

The formulas of Gutin and Deming [9] serve as the basis for our propeller noise calculations. The calculation scheme requires an estimation of the angle between the rotor axis and the direction angle on the observer location θ during the aircraft taxiing:

$$\theta = \arccos \frac{\frac{a^2}{\cos^2 \epsilon} + \Delta S^2 - b^2 - (a \tan \epsilon + \Delta h)^2}{2 \frac{a}{\cos \epsilon} \Delta S}, \quad (5)$$

where the variables are shown in Figure 6, $\Delta S = \sqrt{a^2 + b^2 + \Delta h^2}$, b is the length of the perpendicular segment from the receiver to the projected propeller axis on the horizontal plane passing through the receiver (direction of motion); a is the distance from the projected position of the propeller center to the foot of the perpendicular dropped from the receiver onto the direction of motion; Δh is the difference in geometric height between the rotor center and the receiver; the angle between the direction of the propeller axis and the direction of the aircraft motion is $\epsilon = \alpha + \gamma - \delta$; and $h_m = 1.2$ m is the microphone’s height above the ground.

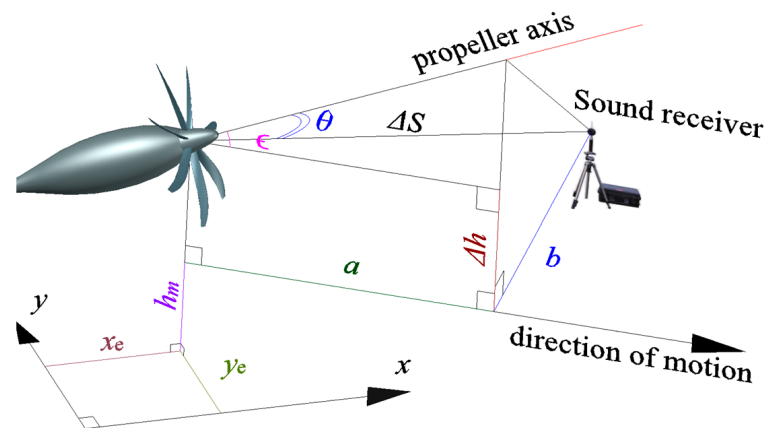


Figure 6. Schematic representation of variables used in SPL estimation.

Distances a and b for engine propellers #1 (a_1 and b_1) and #2 (a_2 and b_2) can be evaluated based on the coordinates of the receiver (x_R, y_R) and the propellers' center (x_{1e}, y_{1e}) and (x_{2e}, y_{2e}) by the following formulas, combined for both engines (1,2):

$$\Delta x_{1,2} = x_R - x_{1,2e}; \quad (6)$$

$$\Delta y_{1,2} = y_R - y_{1,2e}; \quad (7)$$

$$a_{1,2} = (\Delta x_{1,2} \Delta x_s + \Delta y_{1,2} \Delta y_s) \zeta; \quad (8)$$

$$b_{1,2} = (\Delta x_{1,2} \Delta y_s - \Delta y_{1,2} \Delta x_s) \zeta; \quad (9)$$

In case $a = 0$, then $\Delta S = \sqrt{b^2 + \Delta h^2}$, but θ is calculated using the following formula:

$$\theta = \arccos \frac{\frac{1}{\cos^2 \epsilon} + \Delta S^2 - b^2 - (\tan \epsilon + \Delta h)^2}{2 \frac{1}{\cos \epsilon} \Delta S}. \quad (10)$$

For the computation of noise, it is important to note that a propeller does not run at its maximum rotation speed during taxiing, according to Flight Manual [10]. During taxiing, the propeller's rotational speed is 850 rpm and this leads to reduced noise. The Ivchenko progress (IP) propulsion design bureau suggested the usage of a new power engine to operate at the reduced propeller rotational speed of 750 rpm for the HEP aircraft.

The sound exposure level (SEL) for each taxiing trajectory, i , was computed without cutting the top 10 dB, based on the following formula:

$$SEL_i(x, y) = 10 \log_{10} \frac{\int_0^{t_i} p^2(x, y) dt}{p_0^2}, \quad (11)$$

where t_i is the taxiing duration, p is a sound pressure estimated according to Gutin and Deming propellers noise model [9], and p_0 is a threshold sound pressure.

The SEL contours cover a much larger area for the long taxiing path to the East runway end, because it is much longer than the distance to the West end from the apron (Figure 7). As a result, in order to reduce noise, aircraft autonomous taxi operations should be kept as short as possible, possibly due to electric taxis. Additional SEL peaks appear within the noise contour, where the airplane turns and waits the dispatcher's decision. The SEL

comparison between the ATR-72-600 and HEP aircraft indicates that the noise reduction by the HEP aircraft can reach up to 5 dB.

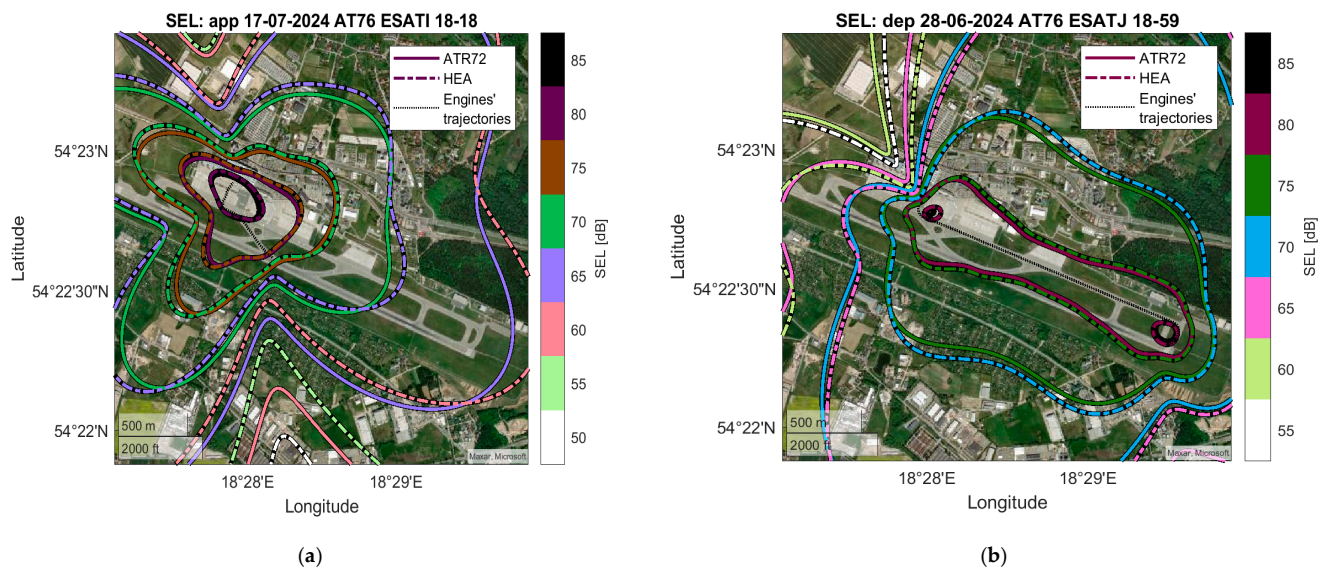


Figure 7. SEL during taxi in operations: (a) shortest taxi in and (b) longest taxi out.

6. Conclusions

The EFACA project study provides an integrated analysis of aircraft noise in flight and ground operations within the EFACA concept aircraft, focusing on NRT that were relevant to aircraft types for a regional airport. This paper focuses on the acoustic performance of a newly developed seven-blade propeller of the EFACA concept for HEP aircraft, which exhibits a significant reduction in tonal noise compared to the ATR-72-600 reference propeller, as independently validated by semi-empirical, analytical, and CAA models. The consistency between the improved NoiTra predictions and measurement data demonstrates the suitability of the updated modeling approach for both aircraft design and airport noise assessment—their results show that the ACARE 2030–35 aircraft noise targets are achievable. Ground-operation analysis shows that aircraft taxi noise exposure is strongly influenced by the taxiing trajectory and propeller rotational speed; their optimal combination during the taxi may lower the SEL by ~5 dB. These results highlight that targeted powerplant improvements combined with optimized operational procedures can provide significant progress towards achieving long-term aircraft noise reduction goals in Europe.

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Conflicts of Interest: Andrzej Chyla was employed by Noise ACH. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ACARE	Advisory Council for Aviation Research and Innovation in Europe
BA	Balanced approach
CAA	Computational aeroacoustics
CFD	Computational fluid dynamics
EFACA	Environmentally Friendly Aviation for all Classes of Aircraft
ICAO	International Civil Aviation Organization
IP	Ivchenko progress
NRT	Noise reduction technology
SEL	Sound exposure level
SPL	Sound pressure level

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